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14. ABSTRACT

Work reported here resulted in the design and fabrication of a space-simulation facility used to test electric thrusters for spacecraft. The facility was specifically designed to accommodate thrusters using condensable metal propellants such as bismuth. Apparatus includes a large 2-m x 4-m vacuum vessel evacuated through three 2,000-liter-per-second turbomolecular pumps, a 20-kW DC power supply, a remote translation system, and computer data acquisition center.

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Final Performance report for period ending 1 September 2004

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submitted to

Dr. Mitat Birkan
Government Program Manager
AFOSR/NA

Project Title

A Ground-Test Facility for High-Power Electric Thrusters Operating on Condensible Propellants

by

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1. Objectives

The goal of the project was to build a facility that will enable development of electric space propulsion systems operating at approximately four times greater power than state-of-the-art while reducing development and flight costs. The research enabled by the facility is in direct correlation with IHPRPT goals, namely to double the performance of rocket propulsion systems over current state-of-the-art, and to decrease the cost of access to space for commercial and military sectors. Specifically, the facility has the unique capability to maintain a space-like environment during operation of electric thrusters that utilize condensable metal propellants. The pumping mechanism, internal volume, and associated apparatus are capable of testing thrusters with power levels greater than 20 kW.

2. Accomplishments

The centerpiece of the fabricated equipment is a 2-m-diameter by 4-m-long space simulation chamber. The vacuum vessel is constructed of stainless steel. One end of the vessel is hinged for internal access. The vessel is evacuated through three 2,000-liter-per-second turbomolecular pumps. The pumps are magnetically levitated and compatible with the harsh conditions anticipated during condensable propellant testing. The turbopumps are backed via a pre-existing mechanical rotary pump in the laboratory. Vacuum instrumentation includes both ConvecTorr and hot-cathode ionization gauges. A photograph of the MTU Isp Lab including the new facility is shown in Figure 1. The new facility is not only robust, but the turbopumps enable fast access to vacuum (Figure 2).

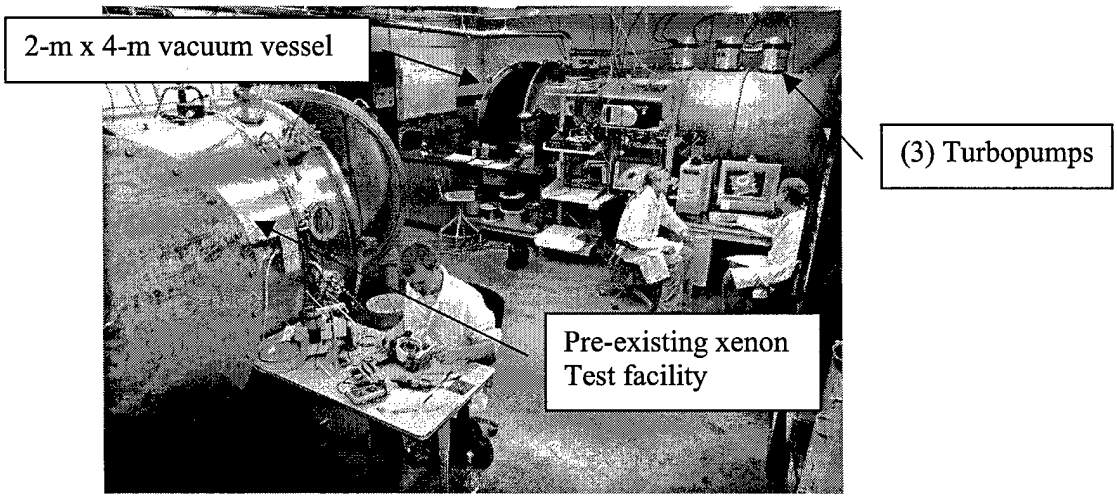

Figure 1. Michigan Tech Ion Space Propulsion Laboratory (Isp Lab). Pre-existing xenon test facility is in foreground, with new 2-m x 4-m condensible facility shown in background.

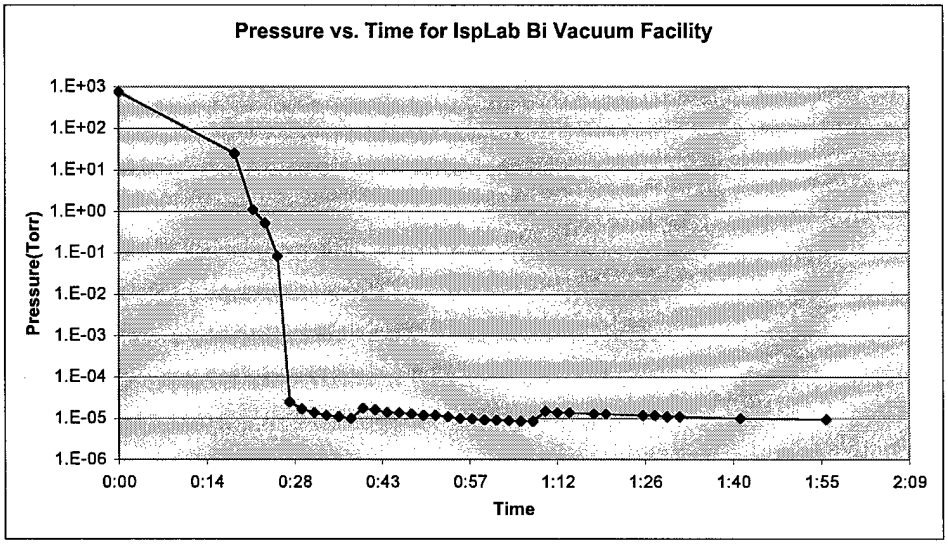

Figure 2. Pressure-vs-time pumpdown curve for the condensible facility. Vacuum of $1x10^{-5}$ Torr can be achieved in less than 30 minutes.

Associated apparatus include a 20-kW (2 kV, 10A) power supply for running high-power thrusters, a computer data acquisition system, and a remote probe positioning system. The probe system enables three-degree-of-freedom manipulation of assets within the chamber at vacuum. The translation envelope fills a sizeable volume within the vacuum vessel, with linear stages of 1 and 1.5 meters. A photograph of the translation system is shown in Figure 3.

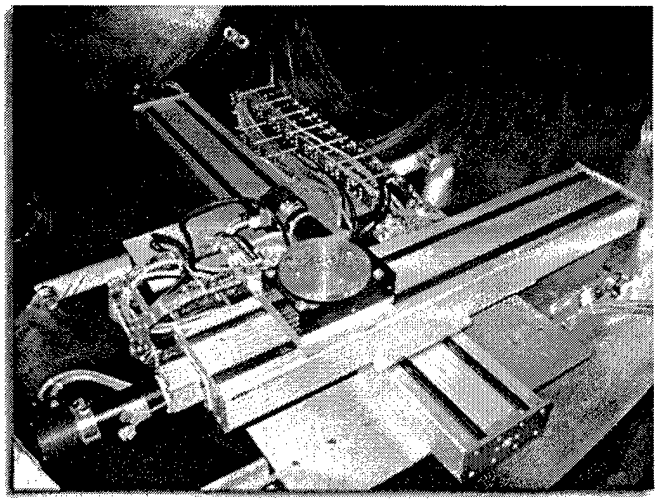

Figure 3. Photograph of remote positioning system within the condensible propellant vacuum vessel. Two linear stages (1-m x 1.5-m) and one rotary stage enable asset manipulation during vacuum testing.

3. Personnel Supported

Work performed here was an equipment-only grant. No personnel were supported during performance. Activities were directed by the PI, Lyon B. King.

4. Publications

No peer-reviewed publications have been submitted yet. Progress is underway to transition two papers presented at the 2004 Joint Propulsion Conference for journal submission later this year.

5. Interactions/Transitions

5.1. Interactions

The PI attended the following conferences and workshops, where he gave oral presentations regarding work performed in the new facility.

- International Space Propulsion Conference, Sardinia, Italy, June 2004.
- Energy Conversion Fundamentals Workshop, Istanbul, Turkey, June 2004.

In addition, the PI and supported graduate students presented two papers on the reported work, along with oral reports, at the AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 2004, Ft. Lauderdale, FL (papers attached).

5.2. Transitions

This research effort has led to a spin-off corporate project involving small business Aerophysics, Inc. along with Aerojet. Aerophysics obtained an SBIR from the Department of Defense (Agency: Air Force, Proposal No: F041-198-2431) in the spring of 2004. The project is titled, "20-kW Bismuth Hall Thruster with Evaporative Anode." Aerophysics is working with partner Aerojet to design and qualify a 20-kW flight-rated Hall thruster using the novel evaporative concept that is the subject of this research. The project is currently in Phase I with the technical work period ending November, 2004.

6. New Discoveries

No new discoveries to report in conjunction with this research grant.

7. Honors/Awards

Since program inception, the PI has received two significant awards:

- Faculty Early Career Award, National Science Foundation, January 2004.
- Presidential Early Career Award for Scientists and Engineers (PECASE), September, 2004.